DOCUMENT-IDENTIFIER: US 20020154671 A1

TITLE: Line selected F2 two chamber laser system

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Abstract Paragraph - ABTX (1):

An injection seeded modular **gas discharge** laser system capable of producing high quality pulsed laser beams at pulse rates of about 4,000 Hz or greater and at pulse energies of about 5 mJ or greater. Two separate discharge chambers are provided, one of which is a part of a master oscillator producing a very narrow band seed beam which is amplified in the second discharge chamber. The chambers can be controlled separately permitting separate optimization of wavelength parameters in the master oscillator and optimization of pulse energy parameters in the amplifying chamber. A preferred embodiment in a F.sub.2 laser system configured as a MOPA and specifically designed for use as a light source for integrated circuit lithography. In the preferred MOPA embodiment, each chamber comprises a single tangential fan providing sufficient gas flow to permit operation at pulse rates of 4000 Hz or greater by clearing debris from the discharge region in less time than the approximately 0.25 milliseconds between pulses. The master oscillator is equipped with a line selection package for selecting the strongest F.sub.2 spectral line.

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Summary of Invention Paragraph - BSTX (19):

[0013] A well-known technique for reducing the band-width of **gas discharge** laser systems (including excimer laser systems) involves the injection of a narrow band "seed" beam into a gain medium. In one such system, a laser producing the seed beam called a "master oscillator" is designed to provide a very narrow bandwidth beam in a first gain medium, and that beam is used as a seed beam in a second gain medium. If the second gain medium functions as a power amplifier, the system is referred to as a master oscillator, power amplifier (MOPA) system. If the second gain medium itself has a resonance cavity (in which laser oscillations take place), the system is referred to as an injection seeded oscillator (ISO) system or a master oscillator, power oscillator (MOPO) system in which case the seed laser is called the master oscillator and the downstream system is called the power oscillator.

Summary of Invention Paragraph - BSTX (21):

[0015] What is needed is a better laser design for a pulse **gas discharge** F.sub.2 laser for operation at repetition rates in the range of about 4,000 pulses per second or greater, permitting precise control of all beam quality parameters including wavelength and pulse energy.

Summary of Invention Paragraph - BSTX (23):
[0016] The present invention provides an injection seeded modular **gas discharge** laser system capable of producing high quality pulsed laser beams at pulse rates of about 4,000 Hz or greater and at pulse energies of about 5 to 10 mJ or greater for integrated outputs of about 20 to 40 Watts or greater. Two separate discharge chambers are provided, one of which is a part of a master oscillator producing a very narrow band seed beam which is amplified in the second discharge chamber. The chambers can be controlled separately permitting optimization of wavelength parameters in the master oscillator and optimization of pulse energy parameters in the amplifying chamber. A preferred embodiment is a F.sub.2 laser system configured as a MOPA and specifically designed for use as a light source for integrated circuit lithography. In this preferred embodiment, both of the chambers and the laser optics are mounted on a vertical optical table within a laser enclosure. In the preferred MOPA embodiment, each chamber comprises a single tangential fan providing sufficient gas flow to permit operation at pulse rates of 4000 Hz or greater by clearing debris from the discharge region in less time than the approximately 0.25 milliseconds between pulses. The master oscillator is equipped with a line selection package for selecting the strongest F.sub.2 spectral line. This preferred embodiment also includes a pulse multiplying module dividing each pulse from the power amplifier into either two or four pulses in order to reduce substantially the deterioration rates of lithography optics. Preferred embodiments of this invention utilize a "three wavelength platform". This includes an enclosure optics table and general equipment layout that is the same for each of the three types of discharge laser systems expected to be in substantial use for integrated circuit fabrication during the early part of the 21.sup.st century, i.e., KrF, ArF, and F.sub.2 lasers.

Detail Description Paragraph - DETX (156):
[0160] The present invention provides a laser system capable of much greater pulse energy and output power than prior art single chamber high repetition rate **gas discharge** lasers. With this system the master oscillator to a large extent determines the wavelength and the bandwidth and the power amplifier primarily controls the pulse energy. The pulse energy needed for an efficient seeding of the power amplifier is can be as low as a small fraction of a mJ as shown in FIG. 6B. Since the master oscillator type of laser is easily capable of producing 5 mJ pulses, it has energy to spare. This additional pulse energy provides opportunities for using certain techniques for improving beam quality which are not particularly energy efficient.

Detail Description Paragraph - DETX (164):
[0168] Coherence of the laser beam can be a problem for integrated circuit fabricators. **Gas discharge** lasers typically produce a laser beam which has low ~~coherence. However, as the bandwidth is made very narrow, a consequence is~~ greater coherence of the output beam. For this reason, some induced spatial in-coherence may possibly be desired. Preferably optical components for reducing the coherence would be added either in the MO resonance cavity or between the MO and the PA. Several optical components are known for reducing

coherence such as moving phase plates or acoustic-optic devices.

Detail Description Paragraph - DETX (189):
[0186] An alternate to the prism based line selector shown in FIG. 16A is a Lyot filter. This filter uses the dispersion of the birefringence of a non-isotropic crystalline material, such as MgF.sub.2, to rotate the polarization of the light depending on the wavelength. By appropriate choice of the thickness of the crystal the total polarization rotation angle of the two VUV wavelengths can be made substantially different. Discrimination of these rotated waves can be achieved by polarization dependent optic elements, such as the Brewster windows of the F.sub.2 laser's **gas discharge** chamber. A single Brewster window of CaF.sub.2 material will show a 1:0.7 ratio of intensity transmission between p-polarized and s-polarized waves respectively. The losses for the s-polarized waves are due to reflections on the surfaces. Since the chamber has two windows these values have to be taken to the 4.sup.th potency to give the correct full round trip ratio of 1:0.24. Optimum discrimination of one of the lines is achieved if the total polarization rotation angle on a double pass through the crystal is exactly 90 degrees. This will be achieved by adjusting the thickness of the crystal to the characteristic quarter wave plate thickness. However, the wavelength of the other line should not undergo such rotation, in fact the total polarization rotation at this wavelength should be a whole multiple of 180 degree (half wave plate) so that the discriminating elements would not affect the transmission of this wave. Thus, the combination of the dispersive birefringent crystal, the polarizing elements (Brewster windows) and the back mirror (for the second pass back through the crystal) suppresses one of the wavelengths while the other remains unaffected.

Detail Description Paragraph - DETX (191):
[0188] FIG. 16C1 shows schematically a line selected F2 laser system with intra-cavity Lyot filter. The resonator is built of high reflective mirror 116A, the birefringent dispersive crystal 116B, the (chamber) Brewster windows 116C and 116D and the output coupling mirror 116E which is partially reflecting. The optical gain is generated within the **gas discharge** in chamber 116F.

Detail Description Paragraph - DETX (199):
[0194] The output coupler of **gas discharge** lasers configured as oscillators is typically a partially reflecting mirror which is usually a wedge shaped optical element with one surface oriented transverse to the beam path and coated to reflect a desired portion of the beam and transmit the remaining portion. The other surface is often coated with an anti-reflection coating and may be oriented as an angle other than transverse to the beam path so that any reflections from this surface is not returned to the gain region.

Detail Description Paragraph - DETX (241):
[0219] Preferred techniques for enclosing the beam path are described in U.S. patent application Ser. No. 10/000,991, filed Nov. 14, 2001, entitled

"**Gas Discharge** Laser With Improved Beam Path" which is incorporated by reference herein. FIGS. 19F 1, 2, 3, 4 and 5 show easy sealing bellows seal used to provide seals between the laser modules but allowing quick easy decoupling of the modules to permit quick module replacement.

Claims Text - CLTX (2):

1. A very narrow band two chamber high repetition rate F.sub.2 **gas discharge** laser system comprising: A) a first laser unit comprising: 1) a first discharge chamber containing; a) a first laser gas b) a first pair of elongated spaced apart electrodes defining a first discharge region, 2) a first fan for producing sufficient gas velocities of said first laser gas in said first discharge region to clear from said first discharge region, following each pulse, substantially all discharge produced ions prior to a next pulse when operating at a repetition rate in the range of 4,000 pulses per second or greater, 3) a first heat exchanger system capable of removing at least 16 kw of heat energy from said first laser gas, B) a line selection unit for minimizing energy outside of a single selected line spectrum, C) a second laser unit comprising: 1) a second discharge chamber containing: a) a second laser gas, b) a second pair of elongated spaced apart electrodes defining a second discharge region 2) a second fan for producing sufficient gas velocities of said second laser gas in said second discharge region to clear from said second discharge region, following each pulse, substantially all discharge produced ions prior to a next pulse when operating at a repetition rate in the range of 4,000 pulses per second or greater, 3) a second heat exchanger system capable of removing at least 16 kw of heat energy from said second laser gas, D) a pulse power system configured to provide electrical pulses to said first pair of electrodes and to said second pair of electrodes sufficient to produce laser pulses at rates of about 4,000 pulses per second with precisely controlled pulse energies in excess of about 5 mJ, E) a laser beam measurement and control system for measuring pulse energy of laser output pulses produced by said two chamber laser system and controlling said laser output pulses in a feedback control arrangement, and wherein output laser beams from said first laser unit are utilized as a seed beam for seeding said second laser unit.